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# Causes of Variability in Concentrations of Polychlorinated Biphenyls and Polybrominated Diphenyl Ethers in Indoor air

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Airborne concentrations of PCBs and PBDEs were measured in offices, homes, public environments, and cars. Variations in concentrations between different rooms in the same domestic and office buildings, showed some intra-building variability for both compound groups. Stepwise multiple linear regression analysis revealed no clear and consistent relationships between log-normalized concentrations of PCBs and PBDEs in homes and offices and factors such as the number of personal computers. This is considered to reflect the complexity of relationships between indoor air contamination and microenvironment characteristics. The influence of personal computers was demonstrated when PBDE concentrations in one office fell appreciably following the exchange of a computer constructed in 1998 for one dating from 2003. Concentrations of PCBs in buildings constructed between 1950 and 1979 were significantly higher ($p < 0.001$) than in those constructed since. When two of the most contaminated cars were omitted as outliers, a significant ($p < 0.01$) positive linear relationship was detected between PBDE concentrations and vehicle age. Concentrations of PCBs and PBDEs were monitored throughout a calendar year in four homes and four offices. Although concentrations in warmer months usually exceeded those in colder months, seasonal variability in indoor contamination appears less significant than observed previously for outdoor air.

## Introduction

Polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are two classes of organohalogen compounds that have found widespread use, and are now ubiquitous in human tissues (*1*, *2*), with concerns about such exposure arising from evidence of their adverse health effects (*3*−*5*). The presence of concentrations of PCBs and PBDEs in indoor air that significantly exceed those found in outdoor air is now well-established (*6*−*15*). In addition to the direct implications that such elevated concentrations have for human exposure via inhalation, there is evidence that indoor airborne PBDEs contaminate indoor dust with potentially substantial impacts on human exposure following its ingestion, depending on the accuracy of the currently uncertain estimates of human dust ingestion, such that dust ingestion has been suggested as one of—if not the—major exposure pathways for toddlers (*15*−*17*). In addition to such direct exposure, the likely influence of indoor contamination on outdoor air concentrations is illustrated by our recent observation of a positive correlation between concentrations of PBDEs in outdoor air and proximity to the center of the West Midlands (*18*). Such observations support concerns that the current indoor reservoir of PBDEs and PCBs represents a substantial source of future dietary exposure to these compounds, following their emission to outdoor media, environmental transport, and incorporation into the food-chain (*19*).

We recently reported the implications for human exposure of a survey of concentrations of PCBs and PBDEs in indoor air from a wide range of homes, offices, public environments, and cars in the UK's second most populous conurbation: the West Midlands. If these impacts are to be minimized, it is important to identify the factors influencing concentrations of PBDEs and PCBs in indoor air. This paper examines the relationship between concentrations of PBDEs and PCBs in samples of indoor air reported previously (*15*) and a variety of factors, such as building age, microenvironment contents, and time of year.

This study focused on those PCB congeners monitored previously by our research group (*8*, *20*, *21*), and on BDEs 28, 47, 49, 66, 85, 99, 100, 153, and 154. These PBDE congeners were selected on the basis that they are the principal congeners monitored in previous comparable studies (*9*, *10*, *14*). Although decabromodiphenyl ether is being increasingly reported, it was not included in this study owing to the difficulties in achieving its reliable determination at the outset of the study (*22*).

Our principal objectives were as follows:

• to examine relationships between the concentrations of PBDEs and PCBs in indoor air and parameters such as room contents and year of building construction.

• to study month-to-month and seasonal variability in airborne concentrations of PBDEs and PCBs in a selected number of indoor microenvironments. This was intended to provide information on: seasonal variations that could be compared with those observed previously for outdoor air; the validity of using a single "spot" measurement of air quality as an indicator of contamination over longer time periods; and, in conjunction with information on any changes in room contents, factors influencing concentrations.

## Experimental Section

**Sampling Strategy and Methods.** These have been described fully elsewhere (*15*), but in summary: samples of indoor air were collected using PUF disk passive samplers between September 2003 and November 2005 in a total of 92 microenvironments within the West Midlands conurbation. Samples (each of 1 month duration) were taken under normal room use conditions from the following microenvironment categories: homes (both living rooms and bedrooms; $n = 31$), offices ($n = 33$), cars ($n = 25$), and public microenvironments ($n = 3$; a coffee shop, a supermarket, and a post office). It is important to note that the PUF disk air samplers employed likely underestimate concentrations of the higher molecular weight congeners as these are more associated with the particulate phase. This effect will be most marked for BDEs 153 and 154 as more than 50% of these congeners have been observed to be present in the particulate phase in indoor air (*10*). Despite this limitation, PUF disk samplers were employed in this study owing to their many advantages over active sampling methods, e.g., low cost that facilitates simultaneous deployment in a large number of locations,

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